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Benchmarking Venezuelan Quality Grades for Grass-Fed Cattle Carcasses

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Abstract: The current Venezuelan beef carcass classification and grading system provide a mean for sorting carcasses into 5 quality grades, designated as AA, A, B, C, and D, in a descending order of expected eating quality. Brahman cull heifers and cows (n = 21 and 18, respectively) and entire males (bulls; n = 17) were finished on native savannah grass, slaughtered and graded by the official standards to compare carcass traits, cutability, cookery traits, and palatability characteristics between graded (A, B, or C) female classes and bulls. The B-graded bulls dressed heavier carcasses, with a more convex leg muscle profile and larger ribeye area ($P < 0.05$) followed by C-graded cows in carcass weight and ribeye area ($P < 0.05$). Marbling score described as "Slight" did not differ among carcass grades (P > 0.05). The B-graded bulls had the highest proportion of total bone-in and boneless cuts ($P < 0.05$); however, carcasses from females surpassed ($P < 0.05$) or did not differ ($P > 0.05$) from bull carcasses in fabrication yield values for 16 of 18 individual cuts. Cooking loss (%) did not vary with carcass grades ($P > 0.05$). Cooked meats from A/B-graded heifers and C-graded cows had lower shear force values, were rated as more tender and flavorful ($P < 0.05$), and exhibited a higher proportion of tender steaks (with shear force < 4.09 kg) than B-graded bull counterparts ($P < 0.05$). Advantageous palatability traits of C-graded cows and A/B-graded heifers fattened on pasture can be used in developing and marketing new value-added products.

Keywords: beef palatability, Brahman, bull, cull cow, cutability.
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Introduction

Since 1997, Venezuela has officially had a dual, voluntary system for grading beef carcasses (Decreto Presidencial No. 1896, 1997) consisting of independent yield and quality grades. The 1997 yield standard is currently not being utilized as it needs a validation study. There are 5 Venezuelan quality grades, designated as AA, A, B, C, and D (in descending order of expected palatability) determined by carcass class and maturity [skeletal, lean and fat color (adipose)] indicators in relationship to the degree of finish (marbling included). All quality grades are applicable to heifers and steers, whereas cows are only eligible for the lower 3 grades. Most cattle raising operations in tropical America do not practice castration to take advantage of faster weight gains, higher feed conversion rates, and a prevailing demand for heavier and leaner carcasses of entire males (Jerez-Timaure and Rodas-Gonzalez, 2005; Arias et al., 2014). Intact-male classes (bulls and

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bullocks) are also ineligible for the top AA quality grade in Venezuela (Decreto Presidencial No. 1896, 1997), but there is still a prevailing demand for quality segregation among carcasses of intact males, and they receive differential wholesale prices according to their quality grades. Conversely, the beef grading differentiation process is commercially useless for carcasses from the female classes because most of the heifers and cull cows are sent to the market in poor physical condition. Their lower-value product is either sent to further processing or sold at wet markets. Hence, producers are currently losing possible value by not targeting grade differentiation opportunities through management practices. Different alternatives have emerged in North America to increase the value of cull cows; namely, feeding high-energy diets to develop a distinct flavor, niche market, muscle profiling from graded cow carcasses, and the use of more accurate prediction equations to estimate lean yield (Stelzleni et al., 2007; Rodas-González et al., 2013; Aalhus et al., 2014). Unfortunately, beneficial results in carcass yield and/or meat palatability of these value-enhancing technologies cannot be easily extrapolated to the vast majority of tropical ecosystems, where raising and fattening of animals solely occur under grazing conditions. Few workers have reported responses in carcass yield and beef palatability of Brahman-influenced female classes fattened under tropical grazing conditions (Pascoal et al., 2009; Vaz et al., 2010); regrettably, carcasses were not graded in those limited studies. Such long-overdue information is crucial to capitalize potential opportunities in the rapidly growing food service and/or retail sector of the region. Clearly, identifying the Venezuelan cull heifer/cow carcass grades with valuable attributes, open new opportunities to better sorting of female carcasses based on expected lean yield and palatability. Hence, the objective of this research was to benchmark graded carcasses from cull heifers and cows with respect to those from bulls on carcass traits, cutability and palatability of *longissimus thoracis* muscles.

Materials and Methods

The study was conducted attending the normative for experimental animals of the Bioethics Committee of the Comisión Nacional de Investigaciones Científicas y Tecnológicas valid since 1999.

Animals

A heterogeneous group of purebred Brahman cull heifers ($n = 21$; ~2.5 yr old), cull cows ($n = 18$; ~4.5 yr old) and crossbred Brahman bulls ($n = 17$; *Bos indicus* × *Bos taurus*, unknown age) was subjected to finishing grazing conditions in a ranch located at the western Venezuelan savannahs. This ranch named Hato Los Valentones, was located in Apure State; 7°54′North of the equator and 43 m above sea level with an average temperature of 22 to 29°C and a distinct rainy season from May to October that featured an annual precipitation ranging from 1,000 to 1,800 mm. Selected heifers (averaging 340 kg live weight) and cows (averaging 410 kg live weight) came from a cow-calf operation next to this ranch owned by the same livestock company, which were culled and removed from the herd due to failure to reproduce during the mating season. Bulls with similar body condition but unknown management history (averaging 405 kg live weight) were purchased from various beef producers in the area for this research trial. All animals were treated against ecto- and endo-parasites and vaccinated against foot-and-mouth disease before entering the trial and finished on native grass pasture (*Leersia hexandra, Hymenachne amplexicaulis, Paspulum plicatulum).* During 120 d, animals were rotated among pastures approximately every 28 d, remaining in each pasture for 4 d. When heifers, cows, and bulls were slaughtered, they had reached an average live weight of 386.46 kg, 456.78 kg, and 465.53 kg, respectively.

Harvesting and carcass evaluation

The animals were transported approximately 524 km from the ranch to a slaughter facility nearby Barquisimeto City, Lara State, where they fasted for 12 h with access to water. After the lairage period, the animals were slaughtered following commercial Venezuelan standard procedures (COVENIN, 1983).

After being chilled for 24 h at 2°C, carcasses were ribbed and evaluated according to the Venezuelan quality grading system (Decreto Presidencial No. 1896, 1997) and the USDA system (USDA, 2016). The current Venezuelan carcass grading system mandates a sex classification of cattle (steers, bulls, young bulls, heifers, and cows) and 2 optional grading systems: 1 by quality and 1 by yield. Individual carcass grading data were collected by 3 meat scientists, faculty members of the Universidad del Zulia. Prior to the trial, a carcass grading training program was conducted in multiple facilities by an experienced meat evaluation trainer of the USDA Agricultural Marketing Service as was previously described in a paper by Huerta-Leidenz (2010).

Both quality- and yield-related traits can be described as follows: (1) leg muscle profile (muscle development of round and rump), where: 1 = very convex; 2 = convex; 3 = straight; 4 = concave; or 5 = very concave; (2) carcass finish (amount and distribution of subcutaneous fat), where:

1 = very abundant; 2 = abundant; 3 = moderate; 4 = slight; or 5 = devoid; (3) back fat thickness (minimum back fat thickness on the loin, assessed at the 12th through 13th rib interface); (4) ribeye area (REA; assessed at the 12th through 13th rib interface), and (5) adipose fat maturity (color of subcutaneous fat), where: 1 = ivory white; 2 = creamy white; 3 = yellowish; 4 = yellow; or 5 = orange. Both quality grading systems were similar in how they evaluated skeletal (bone characteristics and backbone cartilage ossification; 100 = A [younger maturity]; 400 = D [older maturity] and degrees 0 to 99), and lean maturities (color and texture of ribeye muscle; where 100 = A [younger maturity]; 400 = D [older maturity]; and degrees 0 to 99) as well as marbling scores (amount and distribution of intramuscular fat; where: 100 = practically devoid; 200 = traces; 300 = slight; and degrees 0 to 99) were evaluated. Based on the evaluation of the skeletal, lean and adipose maturities, marbling and amount and distribution of subcutaneous fat; heifer carcasses were assigned A or B quality grades, all bull carcasses were graded as B and cow carcasses were graded as C.

Carcass cutability

At 48 h post-mortem, the cold carcass weight was recorded and the left side was fabricated into commercial wholesale cuts. During fabrication, the exterior fat was trimmed off to a maximum thickness of 6.4 mm on the cut surfaces. It is noteworthy that some modifications to the official cut description (COVENIN, 1982) resulted from the packing plant fabrication practices. In this regard, the neck and chuck comprised a single sub-primal (referred as chuck roll), as well as the ribeye and striploin which were boned out as a whole sub-primal (named as "loins"), and the brisket (cutting on the proximal portion of the ribs near of the costal-vertebrae joints and not at half of the ribs; Huerta-Leidenz et al., 2016). A detailed anatomical description of typical, commercial processes of beef carcass fabrication in Venezuela has been reported by Montero et al. (2014) and international equivalences in cut nomenclature were published by Huerta-Leidenz (2013). Accordingly, Table 1 depicts the myology composition of main Venezuelan beef cuts, and the United States equivalents.

Table 1. Myology and nomenclature of main sub-primal beef cuts in Venezuela and approximate equivalences in nomenclature with their United States counterparts[1]

	Cut nomenclature	
Muscle(s)	United States	Venezuela
Psoas major and *psoas minor*, small portion of *quadratus lumborum* and *iliacus.*	Tenderloin	Lomito
Longissimus dorsi (thoracis and lumborum), *longissimus costarum*, *intertransversales lumborum*, *trapezius* and portion of *serratus*, *rhomboideus and deltoideus.*	Rib-eye roll and strip loin	Solomo de cuerito (Grueso y Delgado)
Bíceps femoris, proximal portion	Top sirloin cap/rump steak/coulotte	Punta trasera
Gluteus superficialis, *medius* and *profundus.*	Center cut sirloin/top sirloin butt	Ganso
Semitendinosus	Eye of round	Muchacho redondo
Semimembranosus, abductor, *rectus internus and pectineus*	Top (Inside) round	Pulpa negra
Bíceps femoris distal portion and small portion of *semimembranosus.*	Bottom (Outside) round	Muchacho cuadrado
Rectus femoris, *vastus lateralis*, *medialis* and *intermedius.*	Knuckle	Chocozuela
Tensor fasciae latae.	Tri-tip	Pollo
Gastrocnemius.	Heel of round	Lagarto de la Reina
Transversus abdominis, obliquus abdomis externi e *interni*, *rectus abdominis*, *cutaneus*, *diaphragm.*	Skirt (Inside skirt, flank, flank steak, rose meat and shoulder rose, outside skirt and hanging tender).	Faldas
Intercostales externi and *interni*, *levatores costarum*, *retractor costae*, *transversus thoracis*, *rectus thoracis*, *longissimus costarum,* portions of *longissimus dorsi*, *serratus dorsalis* y *scalenus.*	Rib plate (short ribs + back ribs + chuck short ribs).	Costilla
Digitorum longus, *digitorum brevis*, *digitorum internus*, *digitorum externus*, *flexor carpi radialis*, *extensor carpi obliquus.*	Fore shank and hind shank	Lagarto anterior y posterior
Deltoideus, *infraspinatus*, *teres minor* y *major*, *coracobrachialis.*	Shoulder clod	Paleta
Pectoralis profundi and superficial, portions of *brachiocephalicus* y *sternocefalicus.*	Brisket	Pecho
Supraspinatus	Chuck tender	Papelón
Latissimus dorsi, *longissimus dorsi*, *multifidus dorsi*, *transversus espinalis*, *trapezius*, and *romboideus.*	Chuck roll	Solomo abierto
Infraspinatus	Top blade	Unknown

[1]Source: Huerta-Leidenz (2013), Montero et al. (2014).

The United States nomenclature was used to identify sub-primal beef cuts throughout the manuscript.

After completion of the fabrication process, individual weights of boneless and bone-in cuts were recorded. Thereafter, the trimmed (clean) bone and excess fat components of the bone-in cuts were removed and all resulting co-products (fat trimmings and bone) were weighted again. The total yield of product (i.e., individual subprimal cuts or total amount of lean edible meat) and co-product components were computed as proportions (%) of the cold carcass. For generating variables of significance in the domestic meat trade, products with similar market value were classified into 4 value-based, composite groups (Montero et al., 2014) as follows: (1) High-value boneless cuts [HVC; including tenderloin, "loins", top sirloin cap, center cut sirloin, eye of round, inside round, outside round, knuckle, and tri-tip, (2) Medium-value boneless cuts (MVC; including chuck tender, chuck roll, top blade, and heel of round), (3) Total valuable cuts (TVC; the sum of the high- and medium-value cuts), (4) Low-value cuts [LVC; including bone-in cuts from the forequarter and hindquarter (fore shank and hind shank, brisket, rib plate = short ribs + back ribs + chuck short ribs) plus the skirts (inside skirt, flank, flank steak, rose meat and shoulder rose, outside skirt and hanging tender)].

Procurement of samples for shear force and sensory evaluation

At 48 h post-mortem, two 2.54-cm thick ribeye roll steaks from the right carcass side were sequentially removed from the boneless ribeye starting from the rib-loin interface toward the cranial portion of the *longissimus thoracis* muscle (LDT) and vacuum-packaged for the Warner-Bratzler shear force (WBSF) determination and sensory analyses. The ribeye steaks were randomly chosen, alternating anatomical position for shear force and sensory panel traits. Steaks were not subjected to any intentional aging process because, in Venezuela, most of the beef carcasses and/or sub-primals are marketed within 2 to 7 d post-mortem without applying wet or dry aging, electrical stimulation or any other technology to improve their quality (Rodas-González et al., 2009). Therefore, all vacuum-packaged ribeye steaks were immediately frozen at –30°C and kept at –20°C until further sensorial and WBSF evaluations.

Cooking procedure

Steaks were tempered in a refrigerator at 4°C for 24 h prior to shear force or sensory evaluation. Sample preparation and cooking procedures were followed according to guidelines described by the American Meat Science Association (American Meat Science Association, 2016). Before cooking, thawed weights were recorded. The steaks were cooked in an open electric Oster indoor grill (Sunbeam Products, Inc., model 4777–33, Boca Raton, FL), which was preheated (approximately at 165°C). Steaks were turned once during broiling (at 35°C) and removed from the grill when they reached an internal temperature of 70°C. Once steaks exited the grill, final internal temperature, cooked time and cooked weight were recorded immediately. Cooking loss (%) was calculated using the following formula: [(thawed weight, g – cooked weight, g) / thawed weight, g] × 100.

Shear force determinations

After steaks were cooked, they were allowed to cool down at room temperature. Between 6 and 10 core samples (1.27 cm in diameter), depending on the cross-sectional area within the LDT muscle, were removed parallel to the muscle fiber orientation taking care not to include large areas of fat or connective tissue in each core. Each core was sheared once using a Warner-Bratzler shear machine (G-R Elec. Mfg. Co, Manhattan, KS). The WBSF values were recorded in kg, and the values from the 6 to 10 cores of 2 steaks were averaged for statistical analysis.

Sensory tests with the descriptive trained panel

Steaks for sensory analysis were cooked as described above (American Meat Science Association, 2016). Cooked steaks were trimmed of visible fat and connective tissues. Each steak was cut into 8 to 15 cubed samples (≈1.27 cm^3 of size) of LDT muscle. Cubed samples from each experimental unit were placed on pre-coded discardable, cardboard plates and stored in a preheated oven (at 50°C) for 7 min prior serving to panelists. Cubed samples were served warm, unsalted and unspiced, accompanied with a glass of water that was used to rinse the mouth after tasting each sample.

The trained sensory panel was composed of 6 to 8 trained judges. A detailed description of the panelists' selection and training was reported by Jerez-Timaure et al. (1994) and Huerta-Leidenz et al. (1996). Two cubed samples taken from steaks of each animal were served warm to each judge. Sixteen samples were served in 2 sessions (8 samples per session) in 1 d and 1-hour break between sessions. All samples were evaluated during 2 d for the trained panelists, and samples were served to the panel, balancing graded sex classes. Judges scored the samples for juiciness, muscle fiber tenderness, overall tenderness, amount of connective tissue, and flavor intensity using an 8-point structured rating scale for each attribute (where 1 = extremely dry, extremely tough, extremely tough, an abundant amount of connective tissue, extremely bland, respectively, and 8 = extremely juicy, extremely tender, extremely tender, no connective tissue, extremely intense, respectively; American Meat Science Association, 2016). The values from 6 to 8 trained judges per animal were averaged for statistical analysis.

Statistical analyses

Data were analyzed as a completely randomized design using the MIXED model procedures of SAS (SAS Inst. Inc., Cary, NC) version 9.4 with the sex class plus quality grade combined in a single independent variable. Accordingly, the following combinations were considered as the 4 levels of the class-grade main effect: A-graded heifer, B-graded heifer, B-graded bull and C-graded cow.

Carcass within treatment was used as the random effect. Least squares means for unequal subclass number were separated (F test, $P < 0.05$) using least significant differences generated through the PDIFF option of SAS. The degrees of freedom in the denominator were adjusted using the Satterthwaite procedure.

Additionally, chi-square analysis (Fisher's exact test) was used to test differences among frequencies for class-grade to describe the proportion of tender steaks [WBSF value ≤ 40.13N (4.09 kg)] using threshold values for tenderness classes described by Rodas-González et al. (2009).

Results

Carcass traits

As expected, mean values of traits related to carcass meat yields were in favor of the B-graded bull carcasses, which dressed the heaviest carcasses, with the most convex leg muscle profile, and the largest REA ($P < 0.05$) with respect to the other quality-graded female classes. In the female groups, the C-graded cows yielded heavier carcasses with larger REA, but exhibited a more concave leg profile ($P < 0.05$) than heifers. Differences between A and B graded heifers in carcass yield-related traits were not detected ($P > 0.05$).

Regarding carcass finish, B-graded bulls presented more abundant and uniform distribution of subcutaneous fat cover than C-graded cows ($P < 0.05$), whereas A- and B-graded heifers scored very similar, with intermediate values in carcass finish (Table 2). The B-graded-bulls and C-graded cows had thicker back fat than A-graded heifers ($P < 0.05$), whereas B-graded heifers had intermediate values for this trait. Marbling

Table 2. Carcass traits from graded cull females and bulls[1]

Variable	A-graded heifer (n = 13)	B-graded heifer (n = 8)	B-graded bull (n = 17)	C-graded cow (n = 18)	SEM	P-value
Carcass weight, kg	207.84^{c}	211.38^{c}	266.79^{a}	241.74^{b}	6.78	< 0.01
Leg muscle profile score[2]	3.00^{b}	3.00^{b}	2.70^{c}	3.88^{a}	0.13	< 0.01
Ribeye area, cm^2	55.58^{c}	51.21^{c}	74.99^{a}	66.41^{b}	0.16	< 0.01
Subcutaneous fat cover score[3]	3.69^{ab}	3.62^{ab}	3.29^{b}	3.72^{a}	0.19	0.05
Back fat thickness, mm	1.87^{b}	2.00^{ab}	2.94^{a}	2.83^{a}	0.45	0.04
Marbling score, [4]	336.92	331.25	338.82	303.33	22.09	0.12
Adipose maturity[5]	2.00^{b}	2.00^{b}	2.00^{b}	3.38^{a}	0.11	< 0.01
USDA quality grade, % (n)[6]	Select 100 (13)	Standard 100 (8)	NE 100 (17)	Commercial 5.56 (1) Utility 94.44 (17)	–	–

$^{a–c}$Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]A, B, and C; where A = younger maturity; C = older maturity. Carcass grade according to the 1997 Presidential Decree No. 1896.

[2]Where 1 = very convex, 2 = convex, 3 = straight, 4 = concave, and 5 = very concave.

[3]Where 1 = very abundant, 2 = abundant, 3 = moderate, 4 = slight, and 5 = devoid.

[4]Where 100 = practically devoid, 200 = traces, and 300 = slight; degrees 0 to 99.

[5]Adipose tissue maturity based on fat color, according to the 1997 Presidential Decree No. 1896; where 1 = ivory white, 2 = creamy white, 3 = yellowish, 4 = yellow, and 5 = orange.

[6]Carcass quality grade according to USDA (2016); NE = Not eligible (the grade of a bull carcass consists of the yield grade only).

scores, described as "Slight", did not differ among the experimental groups. As expected, C-graded cows showed the oldest adipose maturity ("yellowish") than the other quality graded sex classes ("creamy white").

On the other hand, except for bulls, which were not eligible for the USDA quality grades, A-graded heifers were equivalent to USDA Select (100%), B-graded heifer to USDA Standard (100%) and C-graded cows to USDA Commercial (5.56%) and USDA Utility (94.44%).

Carcass cutability

C-graded cow, and A- and B-graded heifer carcasses exhibited higher yields of some individual sub-primals like tenderloin, center cut sirloin, knuckle, skirts, hind shank and rib plate ($P < 0.01$; Table 3) than B-graded bull carcasses. In addition, carcasses from B-graded heifer showed the highest yield in top sirloin cap and brisket; while C-graded cow outperformed in inside round and outside round yield ($P < 0.01$). As expected, B-graded

Table 3. Carcass cut-out yield[1] from graded cull female and bull carcasses

Fabrication component	A-graded heifer (*n* = 13)	B-graded heifer (*n* = 8)	B-graded bull (*n* = 17)	C-graded cow (*n* = 18)	SEM	*P*-value
Carcass weight, kg	207.84^{c}	211.38^{c}	266.79^{a}	241.74^{b}	6.78	< 0.01
Individual sub-primal,%[2]						
Tenderloin	2.17^{a}	2.14^{a}	1.91^{b}	2.17^{a}	0.04	< 0.01
Ribeye roll and striploin ("loins")	8.55	8.59	8.15	8.12	0.21	0.17
Center cut sirloin	2.94^{a}	2.92^{ab}	2.80^{b}	3.05^{a}	0.05	< 0.01
Top sirloin cap	1.76^{ab}	1.82^{a}	1.59^{c}	1.67^{bc}	0.05	< 0.01
Inside round	6.47^{ab}	6.51^{ab}	6.17^{a}	6.74^{b}	0.15	< 0.01
Knuckle	3.79^{a}	3.65^{a}	3.39^{b}	3.72^{a}	0.07	< 0.01
Eye round	1.63^{a}	1.69^{ab}	1.79^{c}	1.71^{bc}	0.03	< 0.01
Outside round	3.35^{a}	3.26^{a}	3.28^{a}	3.57^{b}	0.14	< 0.01
Tri-tip	0.97	0.94	0.99	0.99	0.03	0.55
Heel of round	1.45	1.41	1.34	1.41	0.04	0.09
Skirts[3]	3.20^{a}	3.26^{a}	2.77^{b}	3.07^{a}	0.09	< 0.01
Rib plate (Ribs)[4]	8.82^{ab}	9.37^{b}	8.41^{a}	9.47^{b}	0.20	< 0.01
Fore shank	1.73	1.56	1.66	1.80	0.08	0.15
Hind shank	2.76^{a}	2.61^{a}	2.41^{b}	2.68^{a}	0.08	< 0.01
Shoulder clod	8.14	7.99	8.17	7.87	0.13	0.17
Brisket	5.89^{ab}	6.04^{a}	5.53^{bc}	5.41^{c}	0.14	< 0.01
Chuck tender	1.02	1.03	0.97	1.00	0.02	0.30
Chuck roll	10.05^{a}	11.14^{ab}	16.63^{c}	11.84^{b}	0.35	< 0.01
Value-based cut group and co-product, %						
High-value boneless cuts[5]	31.63^{a}	31.52^{a}	30.07^{b}	31.74^{a}	0.30	< 0.01
Medium-value boneless cuts[6]	20.66^{a}	21.57^{ab}	27.11^{c}	22.12^{b}	0.39	< 0.01
Total valuable cuts[7]	52.29^{a}	53.09^{ab}	57.18^{c}	53.86^{b}	0.48	< 0.01
Low-value cuts[8]	22.40^{a}	22.84^{a}	20.78^{b}	22.43^{a}	0.25	< 0.01
Total cuts[9]	74.69^{a}	75.93^{ab}	77.96^{c}	76.29^{b}	0.50	< 0.01
Bone	13.50^{a}	13.16^{a}	11.95^{b}	13.72^{a}	0.36	< 0.01
Trimmed fat	7.91^{a}	8.17^{a}	6.11^{b}	7.51^{a}	0.55	0.03

[a–c]Least squares means for age groups within a row lacking a common superscript letter differ ($P < 0.05$).

[1]Percentage of cold carcass weight.

[2]Individual cuts according to USDA nomenclature.

[3]In the Venezuelan meat jargon skirts refers to the composite group of abdominal and other flat muscles (e.g,, inside skirt, flank, flank steak, rose meat, and shoulder rose, outside skirt and hanging tender).

[4]Rib plate (Ribs) refers to the composite group of bone-in cuts fabricated from the ribcage (i.e., short ribs + back ribs + chuck short ribs).

[5]Includes closely trimmed, boneless cuts from the rib, loin and round: tenderloin, "loins", center cut sirloin, top sirloin cap, inside round, knuckle, eye round, outside round, and tri-tip.

[6]Includes closely trimmed, boneless cuts from the chuck (chuck tender, chuck roll, and shoulder clod), and heel of round.

[7]Total valuable cuts: consists of the sum of the high- and medium-value cuts.

[8]Low-value cuts: ribs, fore shank, hind shank, and brisket, all are bone-in items; skirts are boneless.

[9]Total cuts: the sum of total products (subprimal cuts) of the fabrication process.

bull carcasses had higher proportions of eye round and chuck roll than female graded carcasses ($P < 0.01$).

In value-based composite groups of sub-primals, A/B-graded heifer and C-graded cows had higher yields on both HVC and LVC groups ($P > 0.01$). The B-graded bull carcasses yielded higher percentages of MVC, TVC, and total cuts ($P < 0.05$) than female graded carcasses due to their highest proportion of chuck roll (yielding approximately 5 percentage points more in this cut than female classes). The yield advantages of bulls in boneless lean cuts are partly due to the smaller proportions of bone and trimmed fat ($P < 0.01$). Although B-graded bulls had the highest proportion of total bone-in and boneless cuts ($P < 0.01$) they did not differ or were outperformed by cull female graded carcasses in yield values for most (16 out of 18) individual cuts ($P > 0.05$) particularly from the round.

Cookery traits, WBSF, sensorial evaluation, and proportion of tender steaks

Neither cooking loss nor cooking time were affected by graded sex classes ($P > 0.05$). The results for cooking traits, WBSF, and trained sensory panel scores of ribeye steaks are presented in Table 4.

Steaks from A/B-graded heifer and C-graded cow carcasses presented lower ($P < 0.01$) shear force values and were rated by panelists as more tender ($P < 0.05$; muscle fiber tenderness and overall tenderness) with lesser amount of connective tissue ($P < 0.05$) than their B-graded bull counterparts. However, no differences in juiciness and flavor intensity were detected ($P > 0.05$). The distribution of cooked steaks into tenderness levels is presented in Fig. 1. The highest proportion of tender steaks (> 80%) was derived from A/B-graded heifer and C-graded cow carcasses ($P < 0.01$).

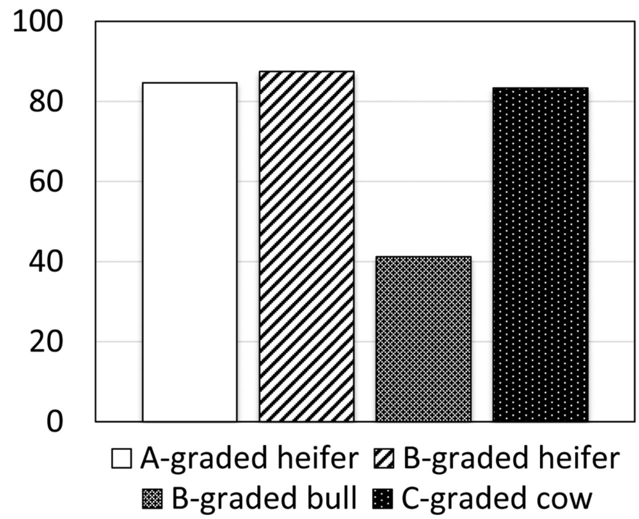

Figure 1. Percentage of tender steaks according to sex class graded carcasses. The proportion of tender steaks was calculated using a threshold value for tenderness classes [WBS value 4.09 kg] as described by Rodas-González et al. (2009). The frequency distribution was tested for significance using a chi-square test ($P < 0.01$).

Discussion

Carcass traits

The Venezuelan carcass quality grading system is a promising instrument for the establishment of equivalency with the US quality system (USDA, 2016), where marbling and physiological maturity are the primary quality-determining factors (Huerta-Leidenz, 2010). Comparisons of sex classes conducted in Latin-America under grazing conditions, with or without pasture supplementation, have documented the advantages in some carcass traits of bulls over their female counterparts (Núñez-González et al., 2005; Coutinho-Filho

Table 4. Cookery traits, Warner-Bratzler shear force (WBSF) and sensory attributes[1] of cooked steaks from graded cull female and bull carcasses

Variable	A-graded heifer (n = 13)	B-graded heifer (n = 8)	B-graded bull (n = 17)	C-graded cow (n = 18)	SEM	P-value
Cooking loss, %	33.10	28.70	29.19	31.83	2.10	0.36
Cooking time, min	55.18	54.94	54.63	55.05	0.40	0.51
WBSF, kg	3.31^{b}	3.27^{b}	4.71^{a}	3.36^{b}	0.28	< 0.01
Juiciness	4.80	4.93	4.86	4.85	0.07	0.93
MFT	4.56^{a}	4.60^{a}	3.79^{b}	4.49^{a}	0.10	0.04
OT	4.39^{a}	4.31^{a}	3.46^{b}	4.10^{ab}	0.10	0.02
ACT	4.05^{a}	4.16^{a}	3.21^{b}	3.91^{a}	0.11	0.02
Flavor intensity	5.88	5.93	5.91	5.95	0.02	0.66

^{a,b}Least squares means within a row lacking a common superscript letter differ ($P < 0.05$).

[1]Based on a descriptive scale for juiciness, muscle fiber tenderness (MFT), overall tenderness (OT), amount of connective tissue (ACT) and flavor intensity; where, 1 = extremely dry, extremely tough, extremely tough, extremely tough, abundant amount of connective tissue, and extremely bland, respectively, and 8 = extremely juicy, extremely tender, extremely tender, extremely tender, no connective tissue, and extremely intense, respectively.

et al., 2006; Mendes-Fernandes et al., 2007; Huerta-Leidenz et al., 2013). Based on a database of 594 beef cattle produced in the main grass-fed beef producing regions of Venezuela, Huerta-Leidenz et al. (2013) reported that bull carcasses were 45 kg heavier than heifer carcasses. In the Central Oaxaca Valley of México, Núñez-González et al. (2005) indicated carcasses from Zebu-influenced bulls and bullocks could be up to 91 kg heavier, with thicker muscle conformation than cow carcasses; in contrast, these authors did not find differences among bulls and cows in marbling score ("traces" to "practically devoid") and back fat thickness (< 2.0 mm), which is in agreement with the results of present study. Similar results were obtained by Mendes-Fernandes et al. (2007) and Coutinho-Filho et al. (2006) on carcass dressing yield and fatness measurements. Regrettably, in those studies, the carcasses were not graded.

Countries with a vast experience in the use of quality grades for beef marketing and pricing, as the United States and Canada, have identified grain-fed cow carcasses (especially beef-type) with desirable carcass characteristics. Although USDA Commercial carcasses from grain-fed cull cows have shown smaller ribeye area and poorer (described as medium) muscle conformation, they also had more marbling and thicker back fat as compared to A-maturity USDA Select carcasses from steers (Stelzleni et al., 2007). Based on the current Canadian grading system for cows (D1, D2, D3, D4; > 50% ossification) a comparison among carcass grades (Rodas-González et al., 2013) indicated that D1 and D2 carcass grades had similar carcass weight and back fat thickness when compared to youthful, A/AA graded carcasses [over (OTM) and under (UTM) 30 mo of age]. Although REA from UTM carcasses was the largest, it was followed in size by D1, D2 and OTM whereas D4 grade showed the highest marbling score (Rodas-González et al., 2013).

Sex class influences rates of fat deposition and muscle development and in controlled studies bulls have consistently exhibited larger, leaner muscles when compared with heifers or cows (Berg and Butterfield, 1968). However, in our study, even though B-graded bulls were superior to C-graded cows and A- and B-graded heifers in carcass yield indicators, they were similar in most of the fatness measurements. Higher marbling levels in C-graded cows were expected, because intramuscular fat is closely linked to fatty tissue development and it is deposited over a long period of growth (Berg and Butterfield, 1968; Robelin, 1986); however, it was not observed in our study, probably due to the low-energy diet (based on native pastures) and the genetic background (purebred and crossbred Brahman) of the experimental group.

Carcass cutability

Several Latin-American cut-out studies, comparing non-graded cows and (or) heifers with castrated or entire males, have reported superiority of males in yield of HVC (or whole hindquarter), MVC (or whole forequarter), TVC (HVC + MVC) and fat trimmings (Huerta-Leidenz and Jerez-Timaure, 1996; Vaz et al., 2002; Coutinho-Filho et al., 2006; Pascoal et al., 2009). However, few studies have compared carcasses of female and male classes in yield of individual boneless subprimals. Coutinho-Filho et al. (2006) indicated when Santa Gertrudis heifers were fed with a high-energy diet their carcasses yielded higher proportions of tenderloin, knuckle and trimmed fat as compared to their bull counterparts; conversely, bulls of the same breed presented higher yield in eye of round. The superior yield of grass-fed cows in some individual HVC presented herein agrees with Pascoal et al. (2009) who found higher proportions of full rump (center cut sirloin + top sirloin cap), center cut sirloin, top sirloin cap, tri-tip and striploin than steers of the same Bradford breed. Contrary to Huerta-Leidenz and Jerez-Timaure (1996), they indicated no differences in bone proportion among sex classes.

Stelzleni et al. (2007) reported USDA Utility carcasses from beef-type cull cows fed a low-energy diet had similar proportions of lean and fat to those of USDA Select A-maturity from steers but yielded higher proportions of lean and lower proportions of fat than USDA Commercial cull cows (either beef or dairy cows fed a high-energy diet). Compared with all other grades of the Canadian grading system, the D3 grade has resulted with the highest proportion of lean in most primals to their lower proportion of dissectible fat despite its lowest carcass weight (Rodas-González et al., 2013). In this study D1, D2, OTM, and UTM grades ranked second after the D3 in lean proportion, followed by D4 (Rodas-González et al., 2013).

The higher percentage of chuck roll yielded by bull carcasses resulted in their greater proportion of MVC. This was expected because most of the muscles from the cervical and shoulder regions have greater development in entire males as compared to other sex classes due to gonadal influences (Berg and Butterfield, 1968; Berg and Butterfield, 1976).

Cookery traits, WBSF, sensorial evaluation, and proportion of tender steaks

Comparisons between non-graded mature females vs. youthful steers have shown disadvantages of cooking traits (e.g., higher cooking loss) and palatability attributes of cow cooked steaks over steers (Vaz et al., 2002). However, the aforementioned differences were not detected when contemporary, young heifers and steers were compared (Jeremiah et al., 1997; Santos, 2005; Lage, 2010; Vaz et al., 2010).

Bull meat can exhibit remarkably deficient palatability attributes with respect to the other sex classes due to the complexity of the connective tissue and a pronounced calpastatin activity influenced by higher testosterone levels (Cross et al., 1984; Morgan et al., 1993). In the extensive literature review of Huerta-Leidenz and Rios (1993) bull steaks were consistently scored by trained panelists as tougher when compared with steers or heifers at the same age. Also, Jerez-Timaure (1994) reported bulls having tougher meat with higher amount of connective tissue than steers and heifers. Many findings reported elsewhere also agree with the results presented herein.

Based on these considerations, the opportunity to expand domestic markets might be achieved utilizing cull heifers and cows due to their higher palatability attributes. The US and Canadian beef industries have been able to establish a palatability muscle profile of cow carcass grades (Stelzleni et al., 2007; Aalhus et al., 2014), which open new opportunities to better sorting cow carcasses and increase the carcass value of identified grades.

Conclusions

The combination of higher dressing yield of B-graded bulls plus their superior cutout performance particularly in the medium-valued cuts supports the long-standing preference of the Venezuelan livestock industry and others in tropical America for raising and harvesting non-castrated males. Undoubtedly, grass-fed meats derived from this quality-graded male class may keep pleasing the predominant demand for leaner beef in price-oriented, Latin American markets. However, the clear, advantageous yield in high-value boneless cuts of Brahman purebred, A/B-graded heifers and C-graded cows compounded with their more desirable palatability attributes, particularly tenderness, indicates a marketing opportunity for adding value to their carcasses and creating new quality-oriented niche markets if fed under these grazing feeding conditions. Although this study involved cattle from few ranches and 1 production system, the results will be meaningful for many ranching operations located in the large low plains (savannahs) of South America (e.g., Brazil, Colombia, Ecuador, and Venezuela).

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